Interfacing FM Systems with Implantable Hearing Devices

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ABSTRACT

Cochlear implant recipients can reduce the challenges they encounter in noisy environments through the use of a remote microphone. Although there are numerous options for delivering the signal from the frequency modulated (FM) transmitter worn by the speaker to the FM receiver coupled to the implant, several have now been verified through research as viable, beneficial arrangements. Recommendations for the settings on the implant include mixing ratio and settings on the FM receivers (i.e., FM advantage). Because coupling of the FM system with the implant cannot be tested with traditional electroacoustic methods, behavioral verification using speech recognition in noise with the implant alone and with the implant plus the FM system is necessary. A variety of resources are available for the audiologist to consult for the specific components, start sequence of switches, and verification protocols. Resources can be found through manufacturer and professional association Web sites.

KEYWORDS: Cochlear implants, FM systems, verification

Learning Objectives: As a result of this activity, the participant will be able to (1) describe the FM components and common coupling arrangements with cochlear implants, (2) describe the research to support the benefits achieved through use of FM systems with implants, and (3) describe the verification techniques to ensure proper settings for maximum benefit in speech recognition.

Cochlear implants (CIs) have had a tremendous impact on the ability of children with severe to profound hearing loss to develop communication. However, communication in the educational setting is compromised by inherent classroom noise. The benefits of implantable devices to restore audibility to persons with hearing loss can be extended to noisy environments through the use of remote microphones. A frequency modulated (FM)

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system operates on radio frequency waves to bring the signal from a remote microphone to a receiver worn by the listener. The variety of coupling options makes the selection and fitting of the FM systems quite challenging, so the audiologist needs several resources. Although FM systems can be used with any implantable aid, much attention has been focused on the issues surrounding the use of FM systems with CIs. Following a review of FM system options, the research to support the use of FM systems with CI users is presented. The article concludes with the fitting and verification protocols that have been recommended in the literature and in professional guidelines.

FM OPTIONS FOR IMPLANTABLE DEVICES

The two basic components to an FM system are the transmitter worn by the speaker and a receiver worn by the listener. These components have many options, which are summarized in Tables 1 and 2 and illustrated in Figs. 1 and 2. The selection of the FM arrangement is generally related to the purpose for which it is used. If the primary use is for a group educational setting, the commonly used versions are the Phonak Inspiro (Warrenville, IL) or the Oticon Amigo. However, if the purpose is primarily individual use, then one might consider the Phonak Smartlink (Somerset, NJ), which has other features such as greater microphone directivity and interaction with Bluetooth technology in cell phones. A review of these and older body-worn connections is provided by Thibodeau.[1]

The FM signal may be received by the implant user by one of two possible methods, either audio or electrical coupling. Audio coupling is the simplest and most compatible across implants because it requires no physical connections and therefore can be used with any device. Although verification is still necessary, there are no special switches or settings that need to be programmed in the implant to benefit from this arrangement. Speech recognition in noise is improved because the voice of the speaker arrives at the implant microphone at an increased intensity level relative to the background noise. One common arrangement for audio coupling is a desktop FM system shown in Fig. 2, in which the teacher's voice is transmitted to a speaker that is placed near the student. Alternatively, the audio signal can be sent to speakers that are mounted on the wall or ceiling. These options have the advantage of benefiting more students than just the one with the implant.

With electrical coupling, also known as direct audio input (DAI) connection, the FM receiver attaches directly to the implant in one of two ways, either through attachment to the implant case or via a cord to the case (Fig. 2). The complexity is increased because there are no standard connections, settings, or startup sequence for the speech processor and FM equipment. Some FM receivers require a dedicated battery, whereas others share the power that drives the speech processor. Typically, the FM receiver for the implant is determined by the type of CI speech processor. Although choices may be limited for the FM receiver, there are many general factors to consider when selecting an FM system to be used with an implant (Table 3).

Some may argue that DAI is not the best connection for the FM system with the implant because the teacher cannot listen to the output to verify the quality of the FM signal. However, it also can be argued that withholding this technology on the basis that an adult cannot verify the signal quality is contradictory with putting on the implant itself. The implant itself is a device that cannot be verified through listening checks. Typically, parents and teachers have established routines for children who receive implants to indicate in some way that they are receiving the implant signal. These same routines can be used to establish that the CI + FM connection is working and that the child is receiving the FM signal.

Because of the numerous cords and adaptors for interfacing FM systems with implants, it is helpful to have a comprehensive reference for determining the appropriate connectors and equipment. There are Web sites where the type of FM transmitter and implant can be entered and the appropriate connectors will be provided (e.g., http://www.phonakpro.com/us/beb/en/support/compatibility/fm_configurater.html

Table 1 Available Options for FM Transmitters

Feature	Variations	Options	Pros	Cons
Microphone	Location	External (lapel)	▪ Clips easily onto clothes.	▪ More likely to pick up noise from clothes. ▪ Located farther away from talker's mouth. ▪ If talker turns head, intensity of microphone signal may vary.
		External (head boom, cheek boom)	▪ Keeps microphone close to the talker's mouth at all times.	▪ Uncomfortable and distracting for some talkers.
		Internal (Lavalier)	▪ Easy to hang around neck of talker. ▪ No microphone cord to snag or break.	▪ More likely to pick up noise from clothes. ▪ Located farther away from talker's mouth. ▪ If talker turns head, intensity of microphone signal may vary.
		Conference	▪ Used in groups or at a table. ▪ Picks up the voices of multiple talkers.	▪ Diminished SNR due to distance from talker.
	Type	Omni-directional	▪ Sensitivity in all directions.	▪ May transmit more noise, especially in large crowds.
		Directional fixed	▪ Able to focus on selected signal with less amplification of surrounding noise.	▪ If positioned incorrectly, the talker's voice may be attenuated.
		Directional user select	▪ User can change the directionality when needed to improve signal reception.	▪ Additional buttons for selection may be confusing.
Channel	Number	Single fixed	▪ Easy for personal use–don't have to worry about changing channels.	▪ May cause interference with other FM users in a confined space (e.g., school).
		Multichannel selectable	▪ If interference is encountered, can change channel easily. ▪ Adds flexibility for use of multiple FM systems in schools.	▪ Options for multiple channels adds complexity and may result in getting on the wrong channel inadvertently.
	Frequency	72–76 MHz	▪ Compatible with older FM equipment.	▪ Prone to interference from unwanted sources.
		216–217 MHz	▪ Less interference; smaller receivers.	▪ Not compatible with older FM equipment.
	Synthesis	Direct (user changes channel)	▪ User is in control of switching channels.	▪ May be tedious if having to change channels for multiple users.
		Automatic (channel changes when in close proximity to receiver)	▪ Convenient when changing channels for more than one user.	▪ Can cause confusion when large group of FM users is in close proximity —channels may change inadvertently.
Controls	AGC	Trimpot	▪ Easy to adjust without connecting to PC.	▪ Can inadvertently be changed.
	Volume	Dial	▪ Easy to adjust without connecting to PC.	▪ Can inadvertently be changed.
Programmable	Channels	Reduce number to those frequently used	▪ Do not have to cycle through channels that are never used.	▪ May restrict flexibility to move equipment to other classrooms.
Batteries	Type	NiCad only	▪ Rechargeable battery is cost efficient over long-term use.	▪ Expensive in the short term.

Table 1 (*Continued*)

Feature	Variations	Options	Pros	Cons
				▪ Need backup in case of battery failure; need access to electrical outlet.
		NiCad and alkaline	▪ Increased flexibility in case of emergency.	▪ Chance of mistakenly charging alkaline battery and damaging system.
	Replacement	User access	▪ Convenient for user.	▪ Increased chance of user error.
		Manufacturer only	▪ Decreases chance of damage to device.	▪ Inconvenient for user if battery needs to be replaced.
Indicator lights	On front	Low battery	▪ Alerts user to change/ charge battery.	▪ May be distracting in public venue with limited lighting, such as a theater.
		FM transmission	▪ Alerts user to function of device.	▪ May be distracting in public venue with limited lighting, such as a theater.
Accessory jacks		Audio input jack	▪ Increases flexibility of device (for use with other devices).	▪ May be confused with jack for charging.
Secondary transmission	Bluetooth		▪ Allows user to use cellular phone with FM device.	▪ Decreases battery life of transmitter.

FM, frequency modulated; AGC, automatic gain control; PC, personal computer; NiCad, nickel-cadmium.
Adapted from American Academy of Audiology. AAA clinical practice guidelines: remote microphone hearing assistance technologies for children and youth birth–21 years. Available at: http://www.audiology.org/resources/documentlibrary/Documents/HATGuideline.pdf. Retrieved July 24, 2009.

and http://www.medel.com/US/MAESTRO-Cochlear-Implant-System/Speech-Processors/Assistive-Listening-Devices.php).

Setup tips include the specific equipment/adaptors needed, as well as the instructions for connecting the devices. An example is shown in Appendix A. There is also an option to create a personalized user's guide as shown in Appendix B. In general, any FM transmitter designed for use with hearing aids (HAs) also can be used with implants. Also, FM receivers that have a standard three-pin Euro connection can be used with implants.

BENEFITS OF FM SYSTEMS WITH IMPLANTS

Cochlear implants have provided significant advantages to persons who could no longer benefit from traditional amplification. These benefits have most often been determined in quiet settings. Expectations by implant users to communicate in noisy environments are typically guarded. Adults may control their environment to reduce the deleterious effects of noise by moving to a quieter place or altering the source of the noise. However, students with implants are often in classroom settings that have typical noise levels that exceed the +15 dB signal-to-noise ratio (SNR) recommended by the American Speech-Language-Hearing Association (ASHA).[2] Knecht et al reported that only 1 of 32 classrooms they measured met these criteria, and some had noise levels as high as 66 dBA.[3] In addition, children are trying to listen to fragments of new auditory information that they are unable to relate to past experiences, which adds to the challenges of listening in noise. It is unfortunate that the benefits afforded by the CI, combined with numerous hours of aural habilitation, could be potentially lost in the noise of the classroom. Even adults with CI who know the language and can predict missing information may experience up to a 60% reduction in speech recognition in adverse conditions.[4,5] Therefore, methods to improve speech recognition in noise for persons who use amplification should be considered for persons who use CIs.

The greatest improvement in speech recognition in noise for persons with hearing loss has been accomplished with wireless technology where a microphone is placed on a speaker and the acoustic signal is sent via FM transmission to a receiver worn by the listener. Lewis et al showed that FM technology

Table 2 Available Options for FM Receivers for Cochlear Implants

Feature	Variations	Options	Pros	Cons
Type	Dedicated	FM receiver works with a single CI model.	▪ Typically interfaces easily and securely within the CI case.	▪ Can only be used with one model resulting in costly upgrades.
	Interchangeable	Receiver attaches to CI via adaptor or cable and can be used with more than one CI.	▪ Flexibility to use with other CIs increases need to have backup equipment.	▪ Adaptor adds another part with the potential to malfunction.
Connection of interchangeable FM receiver	Type	Adaptor at CI base.	▪ May be easily removed when FM not in use.	▪ Adds length/weight to the CI. ▪ May fall off.
		Earhook.	▪ Doesn't add length to the CI.	▪ May need to be removed when FM not in use.
		Cable.	▪ Doesn't add length to the CI.	▪ FM receiver must be attached to clothing.
Channel	Number	Single fixed.	▪ Easy for personal use—don't have to worry about changing channels.	▪ Less flexibility.
		Multichannel selectable.	▪ Good for use in close proximity to other FM users (e.g., schools). ▪ Can be automatically changed to specific channel by transmitter.	▪ May be confusing for some users.
		Multichannel selectable.	▪ Good for use in close proximity to other FM users (e.g., schools). ▪ Can be automatically changed to specific channel by transmitter.	▪ May be confusing for some users.
Batteries	Type	Independent battery.	▪ May increase battery life for CI use.	▪ Adds to troubleshooting.
		Runs off CI battery.	▪ No extra battery required.	▪ May decrease CI battery life.
Programmable	Frequencies	Default channel.	▪ Simplifies the startup for the user so that when turned on, correct channel is received.	▪ If transmitting situation changes, default may no longer be appropriate.
		Channel set.	▪ Reduces chance of inadvertently getting to wrong channel.	▪ Not as flexible if situation changes or equipment needed as backup.
	FM:HA ratio	Adjust level of FM signal re: mic signal.	▪ Allows for customization of system for specific situations and user needs.	▪ May require PC to adjust settings.
	Indicator Lights	Continuous or interrupted.	▪ May indicate reception of FM signal.	▪ May not give indication if battery exhausted.
	Indicator Lights	Continuous or interrupted.	▪ May indicate low battery function.	▪ May decrease battery life.
Switches	Type	Automatic ON/FM.	▪ Less opportunity for user error.	▪ Cannot confirm setting visually.
		Manual ON/FM.	▪ May aid in troubleshooting.	▪ Possibility for user error re: turning on FM switch.
	Mechanical	FM, FM + HA, HA.	▪ Can check settings visually.	▪ Requires manual dexterity ▪ Inadvertently changed.

FM, frequency modulated; CI, cochlear implant, HA, hearing aid.
Adapted from American Academy of Audiology. AAA clinical practice guidelines: remote microphone hearing assistance technologies for children and youth birth–21 years. Available at: http://www.audiology.org/resources/documentlibrary/Documents/HATGuideline.pdf. Retrieved July 24, 2009.

Figure 1 Frequency modulated (FM) transmitter options.

combined with binaural amplification for adults with hearing loss could result in speech recognition performance in noise that was actually better than that achieved by listeners with normal hearing.[6] Numerous options are available for FM technology, including microphone arrangements, receiver features, and connections with other audio electronics such as cell phones. In general, the FM system options for persons with CIs have included soundfield (wall, ceiling, or desktop speakers) and electrical coupling (direct- or cord-connect). There has been some reluctance to investigate the use of FM technology with CIs because the output cannot be verified with the traditional electroacoustic measurements as is done with HAs and FM technology. Therefore, the verification relies on the behavioral performance of the user with the body worn and sound-field FM systems.

One of the first investigations of interfacing FM technology with CIs was conducted with adults who would be reliable reporters of acoustic quality. Ludena and Thibodeau evaluated percent correct sentence recognition in quiet and in noise (+10 SNR) in an auditorium with two young adults with CI experience while using body-worn FM systems (Telex, Comtek, and Phonic Ear).[7] The improvements in speech recognition with the use of the FM systems ranged from 34 to 52%, compared with performance with the CI alone. Subjective reports were favorable with respect to clarity and quality. Davies et al evaluated the effectiveness

Figure 2 Frequency modulated (FM) receiver options.

with a body-worn FM system (Phonic Ear Solaris) with 14 children who used body-worn speech processors (Nucleus Sprint) in a typical classroom.[8] Sentence recognition in noise (0 and −3 SNR) significantly improved in both SNRs while using the FM system. Children with previous FM experience received greater benefit, which suggests that they might have selected higher FM volume levels. However, there was still reticence to use the body-worn FM system in the real world because of the addition of the bulky FM receiver to the already cumbersome body-worn CI speech processor.

Although in the 1990s the body-worn FM systems were routinely used with students with ear-level HAs for improved speech recognition in the classroom, they were not promoted for students with CIs. Often, a desktop FM system was used with school-age children with CIs as a first means to incorporate FM technology while avoiding adding devices on the body; this also allowed easy verification of the FM signal. The negative aspect was the need to carry the speaker (6″ × 4″ × 3″) wherever instruction was occurring. To avoid this inconvenience, wall-mounted speakers to deliver the FM signal also were considered. Speech recognition in noise (+6 SNR) was evaluated by Hanin and Adams in a simulated classroom with a wall-mounted soundfield FM system for six children with CIs (ages 6 to 10 years).[9] Average speech recognition performance improved by 12% while using the soundfield FM system in noise. They recommended soundfield FM systems for students with CIs because of reported electrical interference experienced when using an electrically coupled FM system. Shortly thereafter, however, Crandell et al reported no significant improvements while using a wall-mounted soundfield FM system and live-voice speech presentation.[10] The lack of improved speech recognition in noise (+6 SNR) for the 8 children and 10 adults with CIs may have been the result of the limited gain provided by the soundfield FM system (7 to

Table 3 Considerations in Selecting an FM System

1. Audiological:
A. Hearing Status: conductive/sensorineural/mixed, unilateral/symmetrical, neuropathy
B. Audiogram: thresholds, configuration, stability
C. Speech recognition performance in noise
D. Special considerations: drainage, allergy, atresia
2. Developmental:
A. Age: chronological, developmental
B. Academic performance: better performance = more flexibility
C. Additional problems: cognition, mobility, attention, sensory integration, vision, auditory processing, etc.
3. Listening environment at school:
A. Learning environment: lecture, discussion, team teaching, multiple groups
B. School access: single talker, multiple talkers, technology, etc.
C. School acoustics: room size, reverberation, noise sources
D. Current HAT at school: teacher/peer support
E. Other school locations: gym, therapy, cafeteria, specials
4. Listening environment at home:
A. Activity needs: meals, play
B. Access needs: family, friends, peers, audio from technology
C. Acoustic needs: room size, reverberation, noise sources
D. Other locations: recreation, church, community
5. Technology considerations:
A. Convenience, wearability, reliability
B. Maintenance, ease of monitoring
C. Manufacturer support, compatibility with amplification
D. Compatibility with other devices
E. Signal interference, multiple FM channels
6. Funding considerations:
A. Considered assistive technology under IDEA
IEP–provided by school district; IFSP–State's part C funding
504–provided by local district
B. Interface with personal hearing aids

HAT, hearing assistive technology; IDEA, Individuals with Disabilities Education Act; IEP, Individualized Education Plan; IFSP, Individualized Family Service Plan.
Adapted from American Academy of Audiology. AAA clinical practice guidelines: remote microphone hearing assistance technologies for children and youth birth–21 years. Available at: http://www.audiology.org/resources/documentlibrary/Documents/HATGuideline042208.pdf. Retrieved July 24, 2009.

10 dB). More recent investigations of the benefit of soundfield FM systems for CI listeners resulted in mixed evidence. Anderson et al[11] reported no improvement for 6 students, whereas Iglehart[12] reported significant benefit for 14 students with CIs listening to the signal from the FM transmitter via wall-mounted speakers. The lack of improvement found by Anderson and colleagues was most likely related to a ceiling effect caused by the high performance level when using the CI alone for some students. Therefore, when testing with CI + FM, there was no room for improvement in the percent correct score.

As the options increased for "cube-like" FM receivers that could be interfaced with speech processors, interest in comparing the smaller FM receivers to the desktop systems increased. Schafer and Thibodeau (2004) compared speech recognition in quiet and in noise (+5 SNR) for eight adults with cochlear Nucleus CIs using three FM system arrangements: desktop soundfield (Phonic Ear Toteable), body-worn (Phonic Ear Easy Listener), and cube-like (AVR Logicom CI).[13] Although use of the desktop soundfield condition resulted in an average increase of 6% in speech recognition in noise relative to the quiet condition, this improvement was not significant compared with increases of 28% and 22% in speech recognition in noise obtained with the body-worn and cube-like systems, respectively. For this group of adults, there were no reports of signal distortions when interfacing the FM signal with the microphone signal from the speech processor.

As more cube-like FM receiver options for CIs became available and instances of interference were limited to anecdotal reports, the need to verify benefit with the smaller receivers in children became paramount. Speech recognition in multitalker babble was evaluated when a cube-like FM (Phonak Microlink CI) was interfaced with Nucleus body-worn processors of 12 children by Aaron et al.[14] As expected, the noise significantly degraded speech recognition, and the FM system significantly improved performance for all but one of the participants. Significant benefit also was reported by Schafer and Thibodeau (2003) for 10 children with CIs who completed an adaptive listening task with sentences in noise via four FM system arrangements: desktop soundfield, body-worn, miniature direct-connect, and miniature cord-connect.[15] The children were allowed to adjust the volume on the FM receivers to comfortable listening levels while listening to running speech. The thresholds for speech-weighted noise were obtained via the four FM system arrangements to determine relative audibility levels. The finding of equivalent thresholds across systems suggested that the children were able to adjust the volume settings on the FM system receivers to relatively equal perceptual levels. There were no significant differences across the FM systems—they all resulted in significantly improved performance in noise relative to the implant-alone condition.

Monaural versus Binaural FM Fittings

As the ear-level options for FM receivers became more readily available, additional questions were raised regarding the relative benefit of monaural or binaural fittings. Based on findings of Lewis et al, who reported that binaural FM fitting to ear-level HAs provided significantly greater benefit over monaural FM fittings for adults, one might predict the same for implant users.[6] However, the listening experience for bilateral CI users can be quite different, depending on whether they were implanted simultaneously or sequentially. Furthermore, it has been recommended that monaural implant users continue to use amplification on the unimplanted ear (i.e., bimodal arrangement). The best arrangement of FM systems for bilateral or bimodal CI children was evaluated by Schafer and Thibodeau (2006), who compared speech recognition in noise thresholds for phrases in two groups of 10 children each.[16] The best performance was obtained when the FM signal was received on each side regardless of the bilateral or bimodal arrangement. If only one FM receiver was used, the performance was significantly better when used on the side of the first implant for the bilateral users and on the implant side for the bimodal users.

The research regarding benefit of FM systems with CIs was summarized by Schafer and Kleineck in a meta-analysis.[17] After reviewing nine studies in which benefits of classroom, desktop, and/or direct-connect FM systems were evaluated, they determined that the largest improvement in percent correct speech recognition in noise with the FM system compared with the implant alone was obtained with the direct-connect option (38.0% average improvement) followed by the desktop system (17.1% average improvement). The least improvement was found when using the wall-mounted speakers (3.5%) to deliver the FM signal to the implant users. Such an analysis is the strongest type of evidence to support clinical practice procedures. Therefore, it can be concluded that, on average, students will perform the best with directly connected FM receivers rather than audio coupling options.

The one remaining option that has not been addressed in controlled studies is inductive coupling. Many implants now have a telecoil, which makes them capable of receiving the FM signal from a neck loop. This may be a viable coupling option in some cases, particularly when a student loses the small FM receiver. This larger, sturdier option also may be necessary when teachers need more obvious verification that the student is using the FM system; the small receivers are often not as visible behind long hair covering the ears.

Evaluation of Optimal Settings for Cochlear Implants with FM Systems

The FM technology has now advanced beyond the early questions—whether to interface it with implants and whether to fit it monaurally or binaurally—to further questions surrounding settings on the implant (i.e., mixing ratio) and on the FM receiver (i.e., FM advantage). Early body-worn systems allowed the CI user to adjust the volume of the FM signal to a comfortable level. This was determined in combination with the setting in the speech processor known as the mixing ratio or the relative energy of the signals from the CI processor microphone and the FM transmitter microphone. The comparable adjustment in the ear-level receivers is known as the adjustment for FM advantage. Schafer and Wolfe evaluated the FM advantage settings in five children using Advanced Bionics Auria processors with Phonak MLxS receivers coupled via an iConnect earhook (Fig. 2).[18] Speech recognition in noise was evaluated in CI alone and CI + FM conditions when the FM advantage was adjusted to +10 and +16 dB. Schafer et al found similar results for 17 older children and adults when listening to FM advantage settings in Phonak MLxS receivers of +6, +10, +14, and +20 dB for Advanced Bionics Auria and ESPrit 3G users.[19] Performance increased for the Auria users as FM advantage was increased, but not for the 3G users. This lack of increase for the 3G users was likely because the dynamic range for processing incoming signals was smaller for the 3G and did not allow the increases in the FM signal to be coded for the listeners. The lack of better performance with increased FM advantage settings also was reported for Cochlear Freedom users. Across the Schafer studies, most listeners preferred the +14 dB FM advantage.

The FM advantage also interacts with a setting in the speech processor known as mixing ratio. This setting allows the intensity of the DAI signal to be adjusted relative to the signal from the processor microphone. If the setting is 50/50 (Advanced Bionics processors), the signals are weighted equally. If the setting is 3:1 (Cochlear Corporation), the signal from the processor microphone is given greater weight than the FM signal received via the DAI connection. Wolfe and Schafer[20] evaluated the different mixing ratios in 12 adults wearing Auria units. The results differed depending on whether testing for speech recognition was done in noise or in quiet. Based on their results, they recommended a 50/50 ratio for children to hear the FM and environmental signals optimally. For adults, they suggested allowing them to switch to the 30/70 setting for improved hearing in noise. Because they found that this setting limits hearing environmental signals, they recommended it only be available for adults who can judge the relative importance of hearing the signals from the FM versus the implant microphones.

Rather than having one fixed FM setting, a new FM receiver (Phonak MLxi) has adaptive FM advantage. The adaptive FM processing adjusts the output of the FM receiver based on the ambient noise. If the transmitter detects that the ambient noise exceeds 57 dB sound pressure level (SPL), a signal is sent to the FM receiver to increase the gain of the FM receiver and therefore increase the FM advantage to a maximum of +24 dB. The transmitter and the receiver must both have the adaptive processing capability to experience the benefit of increasing the SNR. Wolfe et al evaluated 13 subjects with Advanced Bionics implants and 12 subjects with Cochlear Corporation implants when using traditional fixed versus adaptive FM advantage in background noise levels of 55, 65, 70, and 75 dBA.[21] The listeners with Advanced Bionics implants showed significant improvement in speech recognition as noise level increased. The listeners with implants by Cochlear Corporation did not show the improved performance until the autosensitivity feature was activated. With that feature activated, the likelihood that signals from the FM transmitter will be compressed is reduced and the effects of adaptive FM advantage can be observed. They also found that speech recognition in noise when listening only through the implant microphone (FM microphone muted) was significantly better with the autosensitivity feature activated. Based on these results, Wolfe and colleagues recommended using the default program settings for Advanced Bionics CI users and enabling the autosensitivity feature for Cochlear Corporation CI recipients to optimize speech recognition in noise with dynamic FM and also without FM.

Research has supported the use of FM systems with CIs through a variety of coupling arrangements. The best arrangement is to use an electrically connected FM receiver on each side, whether the child wears two implants or an implant and an HA. For those bilateral arrangements that require a cord connection, a y–cord may be used so that only one FM receiver is needed. However, no data to support this arrangement have been reported. Also there are no published studies of using FM systems with bone-anchored HAs; manufacturers provide instructions for DAI connections of FM receivers. There will continue to be new arrangements that will require verification and comparison with previous technology through research. New connections also should be evaluated, first with adult implant users so that fine acoustic variations in quality can be adequately described.

CHALLENGES WITH FM SYSTEMS WITH IMPLANTS

Although studies have shown significant benefits for speech recognition when using FM systems with implants, some challenges inherent in these systems can be addressed efficiently when known in advance. Some of the challenges are specific to the equipment arrangement and some are related to general transmission of FM signals. The issues related to specific equipment arrangements are reviewed in this article, with suggestions to alleviate them. The challenges relating to more general educational issues are not so easily remediated and typically are addressed through increased communication among professionals.

Following the initial challenges associated with body-worn FM receivers adding bulkiness to small bodies already laden with body-worn speech processors, smaller FM receivers were welcomed but came with the disadvantage of less secure connections. When adapters to hold the FM receiver to the ear-level speech processors would fall off, various taping efforts were tried. An acceptable, economical tape option was the use of “paper tape,” which does not leave a residue on the case. A supply of this tape in the classroom for daily use may prevent hours of searching for lost receivers.

With the advent of various ear-level designs, new connectors for existing FM receivers were developed. When the connector provided the power source for the FM receiver, it was important to verify that adequate power was received. All the FM components could be working perfectly in an HA arrangement and then fail to work when used with an arrangement where the power was supplied in the connector. In one case, it was determined that the slightly thicker batteries by a specific manufacturer made better contacts. Having an FM receiver that contained light-to-signal FM receptions would be very helpful to confirm the power supply was adequate.

Table 4 Optimal FM Frequencies to Use When Interfacing FM Systems with Cochlear Implants

Phonak Number	FM Frequency
09	216.2125
12	216.2875
13	216.3125
16	216.3875
17	216.4125
18	216.4375
61	216.5125
62	216.5375
52	216.5750
64	216.5875
65	216.6125
68	216.6875
73	216.8125
57	216.8250
76	216.8875

FM, frequency modulated.
From Phonak Inc., Warrenville, IL. Recommended FM channels for use with cochlear implants (personal communication, March 30, 2009).

The miniaturization of the FM receiver so that it could be attached to the ear-level processor resulted in it being positioned close to the magnetic coil where the electrically coded signals were transmitted across the skull to the internal components. In some cases, this close proximity of the FM receiver to the transmitter coil resulted in audible interference described as a high-pitched wavering signal. When the coil was removed from the speech processor, the interference detected via a listening earphone disappeared. The FM manufacturers reported a set of optimal frequencies to be used with CI arrangements to avoid frequency interference (Table 4).

A final challenge when interfacing FM systems with CIs relates to the diversity of the professionals involved in fitting the systems. Generally, an audiologist who specializes in mapping CIs determines the optimum settings in the implant. Then the child receives the FM system through the educational system, which has a different audiologist. Unlike HAs, CIs cannot be connected to a computer through a standardized interface and internal settings that are read digitally. The educational audiologist must communicate with the mapping audiologist to know the mixing ratio or the program designated for FM use. The educational system is not responsible for the actual mapping of the CI according to the ASHA.[22]

The regulations in the Individuals with Disabilities Education Act (IDEA) now specifically state that mapping is not a related service, and also clarify that optimization does refer to mapping a CI. Therefore, school districts are not required to provide optimization services to comply with IDEA. Further, the language makes clear that a child with a CI or other surgically implanted medical device is entitled to those related services (e.g., speech and language services, audiology services) that are required for the child to benefit from special education, as determined by the child's Individualized Education Plan (IEP) team.

Therefore, communication between the implant audiologist and the educational audiologist is critical for documenting the settings to conduct efficient behavioral verification procedures. Although these are only a few of the challenges with interfacing FM systems with CIs, they are examples to illustrate that solutions can be found. Often the solutions require additional effort to establish ongoing communication or to verify appropriate connections. Regardless of the arrangement, there will need to be close monitoring to ensure the child is responding as well in quiet and even better in noise situations when using the FM technology.

VERIFICATION OF FM WITH IMPLANTABLE DEVICES

The verification of FM systems with implants varies depending on the options available on the processors. Some speech processors allow connection of listening earphones for checking by someone with normal hearing, and others can be verified only through informal and formal procedures with the implant user. First, one must ensure the connections and settings are correct. Next, informal measures are necessary to verify functioning of the local and remote microphones. Formal objective measurements may be used to compare different settings within an arrangement or the speech recognition benefits across different types of FM systems.

Table 5 Contact Information for Manufacturers of FM Systems and Cochlear Implants

For Cochlear Implants by:
Cochlear (800–523–5798): www.cochlearamericas.com
Advanced Bionics (800–678–2575): www.bionicear.com
MED-EL (888–633–3524): www.medel.com
For FM Systems by:
Phonak (800–679–4871): www.phonak.com
Oticon (800–526–3921): www.oticon.com
Sonovation (800–462–8336): www.avrsono.com
Comtek (800–469–3463): www.comtek.com

Preassessment Verification

Before any informal or formal checks, the proper equipment arrangements must be confirmed by reviewing information provided by the manufacturers of both the implant and the FM system. Important information is provided on their Web sites regarding the FM-to-CI connections. Contact information for several manufacturers is provided in Table 5. To assist with documentation, a form was included in the American Academy of Audiology (AAA) Clinical Practice Guidelines (Fig. 3).[23] Because numerous options are currently available, the form is needed to record the FM/CI equipment, model information with serial numbers, processor and FM settings, and speech recognition results. Some information regarding the CI settings may only be available through consultation with the implant audiologist who does the mapping of the implant system. For example, the implant audiologist sets the mixing ratio in the mapping software. For the Advanced Bionics Auria and Harmony speech processors, the mixing ratio may be 50/50, which results in equal emphasis for the signal from the microphone of the speech processor and FM signals, or 30/70, which results in the processor signal being attenuated by 10 dB relative to the FM signal. Two other possible settings are (1) auxiliary input only, where the processor microphone is deactivated (i.e., FM only), and (2) processor microphone only, where the auxiliary input is deactivated. For the Cochlear Corporation's Freedom Speech

FM FITTING and VERIFICATION WORKSHEET: Cochlear Implant

Name: ______________________________ Date of Birth: ______________

Examiner: ______________________________ Date of Eval: ______________

School District/Agency: ______________________ Default FM Channel: __________

	Right Ear: CI or HA	Left Ear: CI or HA
Equipment Verification	Manufacturer:	Manufacturer:
	Model:	Model:
	Serial No:	Serial No:
	Use Settings:	Use Settings:
	FM receiver manufacturer and model:	FM receiver manufacturer and model:
	FM receiver Serial No:	FM receiver Serial No:
	Audio shoe/CI Adapter:	Audio shoe/CI Adapter:
	FM startup sequence:	FM startup sequence:
	FM transmitter manufacturer & model: Transmitter serial number:	Type of microphone:
Listening and Behavioral check	☐ Listening check to HA/CI alone ☐ Listening check for FM signal ☐ Informal Behavioral check HA/CI alone ☐ Informal Behavioral check FM Comments:	☐ Listening check to HA/CI alone ☐ Listening check for FM signal ☐ Informal Behavioral check HA/CI alone ☐ Informal Behavioral check FM Comments:

Formal Behavioral Check

Initial Noise Level **FM Receiver Setting: ☐FM ☐FM+M**

Condition		Speech dB HL	Noise dB HL	HA or CI Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
QUIET	BCI50$_{HL}$	50	None		Off			
	BFMCI50$_{HL}$	50	None					
NOISE	BCI50/50$_{HL}$	50	50		Off			
	BFMCI50/50$_{HL}$	50	50					

Adjusted Noise Level (if necessary) **FM Receiver Setting: ☐FM ☐FM+M**

Condition		Speech dB HL	Noise dB HL	HA or CI Settings	FM Settings	Speech List	# of Stimuli	Percent Correct
NOISE	BCI50/__$_{HL}$	50			Off			
	BFMCI50/__$_{HL}$	50						
NOISE	BCI50/__$_{HL}$	50			Off			
	BFMCI50/__$_{HL}$	50						

Summary:

Note: CI=Cochlear Implant; FM=Frequency Modulated; HA=Hearing Aid; B=Behavioral

Figure 3 FM/CI verification form from American Academy of Audiology Clinical Practice Guidelines. FM, frequency modulated; CI, cochlear implant; HA, hearing aid; HL, hearing level; B, behavioral. (Adapted from American Academy of Audiology. AAA clinical practice guidelines: remote microphone hearing assistance technologies for children and youth birth–21 years. Available at: http://www.audiology.org/resources/documentlibrary/Documents/HATGuideline042208.pdf. Accessed July 24, 2009.)

processor, the mixing ratio may be 1:1—where there is equal emphasis for the processor and FM microphones—2:1, 3:1, or 10:1, which correspond to the processor mic being attenuated by 6 dB, 9 dB, or 20 dB, respectively. The 3:1 mixing ratio is the manufacturer's default setting.

The startup sequence for the implant and FM systems recommended by the manufacturer also should be recorded on the documentation form. All of the components should be in the off position when the FM receiver is connected to the processor. In most cases, the implant is turned on first followed by the FM receiver if it has a power switch. The FM transmitter is then turned on last. There are some exceptions to this sequence, however, and deviations from the recommended order could result in malfunction.

Informed Assessment

Two steps to the informal assessment first involve just the implant audiologist and second the educational audiologist who works with the student. Initially, the audiologist will want to verify that the signals are received through both the local microphone on the CI speech processor and through the remote microphone on the FM transmitter. Some speech processors allow checking these signals through the use of a listening earphone, as is shown in Fig. 4. For Cochlear's Sprint and Freedom body-worn processors and Cochlear's ESPrit 3G and Freedom ear-level processors, the listening earphone can be attached at the same time as the FM receiver. While listening through the listening earphone, the FM and processor microphones can be verified by tapping each microphone separately to determine that both signals are received at the speech processor. It is important to note that activation of the listening earphone requires an increased battery drain. Therefore, in the Cochlear ESPrit 3G processor, there is an option to deactivate the port for the listening earphone. In the newer Freedom processor by Cochlear, the listening earphone option remains active for only 90 seconds to limit battery drain. The check via the listening earphone must be made as soon as the processor is activated.

Some CI speech processors do not have separate ports for the FM receiver and the listening earphone, so the FM equipment will need to be verified with an HA. Knowing that the FM receiver and transmitter are functioning before connection to the CI will facilitate troubleshooting. If the FM system is working correctly with an HA, then any problems that occur when used with the CI system could be attributed to the connection of the FM receiver to the processor. The functioning of some FM receivers, such as the Phonak MLCI+, can be verified through the use of a small speaker as show in Fig. 5. When the signal from the FM microphone is heard through the connection of the MLCI+ to the speaker, several components are verified including the transmitter and microphone, the battery in the MLCI+ receiver, the volume setting on the MLCI+ receiver, the connector cord, and the FM receiver channel.

Figure 4 Listening earphone attached to Cochlear Corporation's ESPrit 3G Speech Processor.

Figure 5 Verification of Phonak MLCI + MLxS FM receiver with Radio Shack speaker.

The second step in the informal assessment following the initial equipment check is to verify the arrangement on the user. A common listening check arrangement for CI/FM verification with a child is to turn on the combined CI/FM devices in the recommended sequence and present simple directions while standing behind the child. If the child responds correctly, it could be the result of hearing via the local microphone or through the FM transmitter microphone. Furthermore, if a child wears bilateral processors, it is tempting to get all the CI/FM devices in place and present simple speech while standing behind the child. However, when the child responds correctly, it is unknown if each speech processor was functioning adequately.

If the child wears bilateral CIs or CI plus HA, each side should be verified separately. Verification of each side requires two steps: (1) confirm the child receives input from the local CI microphone, and (2) confirm the child receives input from the FM microphone. The CI microphone typically remains active while the FM system is connected so that the child hears the speaker as well as his or her own voice and other voices nearby. One exception is the Advanced Bionics body-worn Platinum Sound Processor, which requires a separate microphone to be added to the FM receiver. With this additional microphone, the child can self-monitor and hear the signals nearby.

To confirm that the CI user receives input from the local CI microphone while the FM system is connected, the FM microphone should be placed across the room where there is no direct input while simple directions are given to the child by someone who is standing directly behind the child. For older children, a more challenging task may be used such as naming the capital or a sports team associated with a given state. For younger children, speech awareness may be verified using play audiometry techniques.

Following verification of the local microphone, the remote microphone on the FM transmitter should be evaluated by repeating the speech recognition task while standing in an adjacent room. It is important to be far enough away that the child does not hear through the CI local microphone. In addition, no visual speech recognition cues should be available so that the responses from the child can be interpreted as verification of the signals received through the CI/FM system. After verification of the local and remote microphones for one implant, it should be turned off and the process repeated for the second implant.

Formal Assessment

After the equipment has been verified through informal measures, a formal assessment of benefit can be performed to ensure the proper settings and relative benefits from the local and remote microphones. The purpose of this formal assessment is to determine if there is a significant increase in speech recognition performance when listening through the CI + FM arrangement relative to the CI alone. Appropriate speech materials for the child's age that have multiple lists must be selected. Background noise should be added to degrade the performance with the CI alone so that the benefit of using the FM system with the CI may be observed. The noise may be speech-weighted continuous noise or fluctuating classroom noise. One possible test arrangement recommended by the AAA Clinical Practice Guidelines is shown in Fig. 6.[23] The child is seated in the sound booth with two speakers, one at 0 and another at 180 degrees. The examiner is seated at the audiometer outside the sound booth with the FM transmitter in proper position but turned off. The speech is presented via monitored live voice at 50 dB hearing level (HL) while competition is presented also at 50 dB HL. Although the live-voice testing adds variability compared with using recorded materials, it is important to evaluate the speech recognition performance through the transmitter microphone rather than via a DAI connection that would be required for recorded materials. Furthermore, the benefit received through the use of an FM transmitter is typically several times greater than the possible variability.

The first step is to evaluate the speech recognition performance via the CI alone at 0 SNR. This behavioral test arrangement without the FM transmitter activated can be

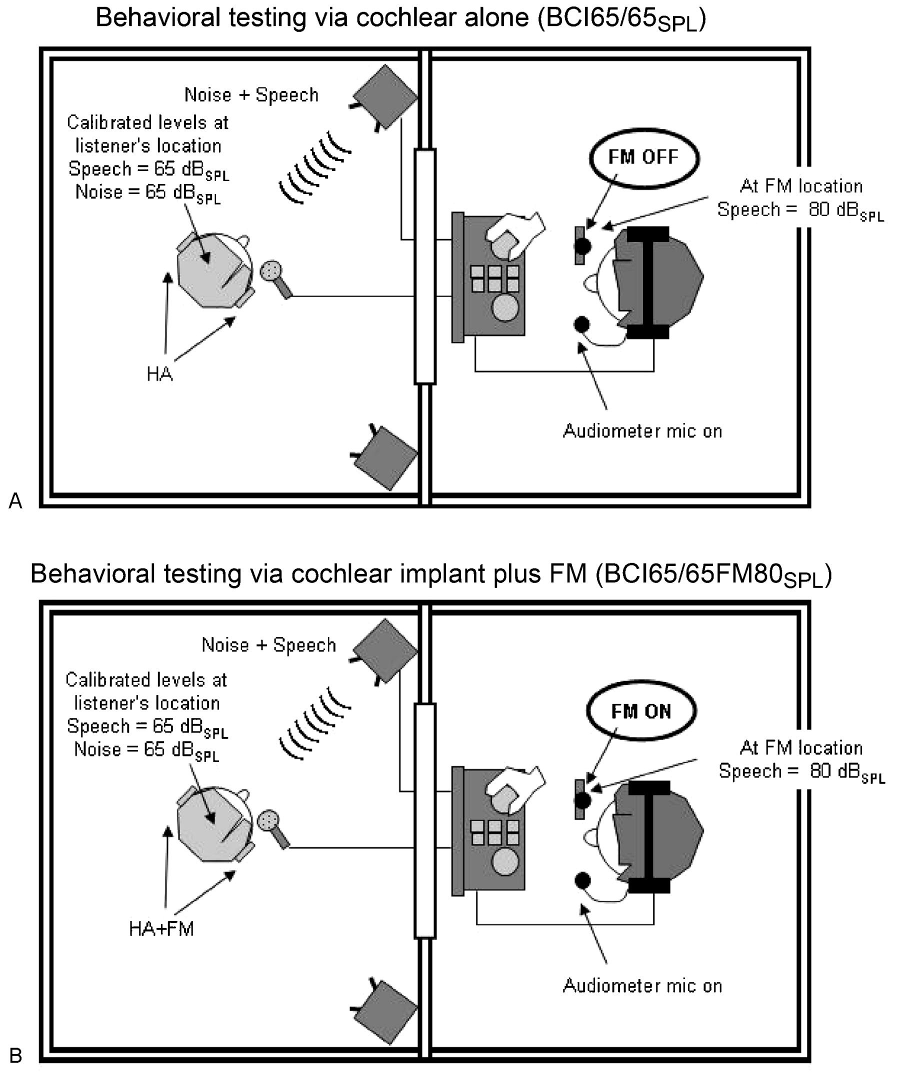

Figure 6 Test arrangement for behavioral verification of speech recognition of CI + FM arrangement. CI, cochlear implant; FM, frequency modulated; B, behavioral; HA, hearing aid; SPL, sound pressure level (Adapted from American Academy of Audiology. AAA clinical practice guidelines: remote microphone hearing assistance technologies for children and youth birth–21 years. Available at: http://www.audiology.org/resources/documentlibrary/Documents/HATGuideline.pdf. Accessed July 24, 2009.)

referred to as BCI50/50, where the first letter refers to the type of testing (B for behavioral), the next letters refer to the equipment used (CI for cochlear implant; FM for frequency modulated system), and the numbers to refer to the signal and competition levels. The first number always refers to the signal level, and the second number refers to the competition level. If the initial performance is better than 80%, then the noise must be increased to −5 dB SNR and another list presented.

Following the assessment of the performance for BCI50/50, the FM transmitter is activated, and the signal and noise levels remain the same. If a −5 dB SNR was needed to reduce performance in the CI condition, the benefit of adding the FM system is tested in that same −5 dB SNR. If time permits, it is suggested that the measures be repeated in quiet (BCI50 and BCIFM50) to ensure that adding the FM system does not alter the signal quality in the quiet arrangement.

The results of a similar protocol with eight students with CIs, mean age 8 years, conducted by Thibodeau et al[24] resulted in an average improvement in speech recognition of 30%. Students were tested in an SNR of +5 dB, as is recommended in the ASHA Desk Reference's guidelines,[25] rather than the 0 dB SNR mentioned in the current AAA Clinical Practice Guidelines.[23] A variety of CIs and FM systems were worn by the eight students, who were evaluated at their individual user settings. All of the students showed improved performance with the FM system without the benefit of any fine tuning to the CI or FM settings. The 95% confidence interval for improvement ranged from 13 to 47%. Although the sample size was small, one may consider 13%, the low end of the confidence interval, as an estimate of the minimal improvement expected when an FM system is used with a CI at +5 dB SNR. When tested with the currently recommended 0 dB SNR, the improvements may be even greater. If speech recognition does not improve by more than 13%, then changes to the FM receiver settings or the FM device arrangement should be considered.

One limitation of the AAA Clinical Practice Guidelines is the use of a percent correct scoring because it has high variability. For example, Thornton and Raffin showed that for the typical speech recognition list that has 25 words, a 20% difference is the minimum change needed for significance if the initial score without the FM system is between 16 and 80%.[26] Therefore, the use of an adaptive speech recognition protocol may be considered. Schafer and Thibodeau (2006) used an adaptive task involving simple phrases such as "brush his teeth" and "comb his hair."[16] They showed an average 13 dB improvement in speech recognition threshold in noise when the FM system was combined with a single CI. An additional 3 dB improvement on average was measured when the FM system was bilateral rather than monaural. In percent correct, this translates to an ~30% increase when adding the FM signal to the second side.

Another limitation of the formal assessment recommended by the AAA Clinical Practice Guidelines is that the child must be capable of giving some consistent response to speech.[23] Adaptations to testing routines may be necessary and should always be noted in the records. For a very young child, the stimuli may be body parts presented in both conditions, CI alone and then CI + FM. Although the probability of guessing is higher than for a longer list of open set materials, it can be an indication that the child is performing better with the CI + FM than the CI alone.

When limited language development precludes conducting verification with speech recognition, speech awareness tasks may be used in the same test arrangement suggested in Fig. 6. Rather than measuring the percentage of words correctly repeated, the level at which the examiner's voice may be detected in the presence of 50 dB HL speech noise may be determined first with the CI alone. Then with the CI + FM arrangement, speech awareness may be measured at the lowest limit of the audiometer because the voice is sent via the FM transmitter at a constant intensity level. If the speech awareness threshold does not improve within the CI + FM arrangement, further investigation is required to verify adequate functioning of each component.

SUMMARY

Children with CIs can receive significant benefit in speech recognition through the use of an FM system in noise environments. However, because of the numerous settings and equipment arrangements that may be selected for an individual child, protocols and Web sites for equipment connections and verification of performance to determine the optimum settings/arrangement must be consulted. The AAA Clinical Practice Guidelines for the Fitting and Monitoring of FM Systems suggest methods for behavioral evaluation of FM systems with implants. The average improvement in percent correct score when using the FM system with the CI was 30%. Although the CI + FM fitting may be verified in the clinical setting, it is especially critical to follow-up with classroom observations for school-age children to ensure a child is using the FM transmitter/receiver properly and that the child is responding to signals that are presented through the FM transmitter in the educational environment. As technological advances continue, there will be increasingly novel ways for students to benefit from FM technology. For example, students may easily hear up to 10 speakers in a room who are wearing FM transmitters that are networked to transmit on a single channel. This may be especially useful in situations with multiple instructors, such as marching practice in a large high school band program. In addition to multiple band directors giving instructions from around the field, the challenge of transmission range across a football field can be addressed through the use of a wide-area transmitter. This is just one example of how advances in technology will continue to expand opportunities for persons with impaired hearing.

ABBREVIATIONS

AAA	American Academy of Audiology
ASHA	American Speech-Language-Hearing Association
BCI	behavioral testing with the cochlear implant
CI	cochlear implant
DAI	direct audio input
FM	frequency modulated
HAT	hearing assistive technology
HL	hearing level
IDEA	Individuals with Disabilities Education Act
IEP	Individualized Education Program
IFSP	Individualized Family Service Plan
SNR	signal-to-noise ratio
SPL	sound pressure level

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APPENDIX A Example of downloadable setup tips for interfacing frequency modulated (FM) systems with implants. FM, frequency modulated; CI, cochlear implant.

Setup Tips for Advanced Bionics Auria or Harmony Cochlear Implant with Phonak FM System.

Available at: www.phonakpro.com/us/bzb/en/support/compatibility/fm_comfigurator.html.

For the selection you have made, you will need:

1. The Harmony/Auria BTE Processor

DPAI* = Yes

*DPAI= Designated Programmable Audio Input.

"DPAI: Yes" means the external device may be connected via an independent audio input whereby gain and balance parameters can be finetuned.

Note: To ensure correct FM level, always use the FM Successware to program the MicroLink FM receiver selecting the corresponding CI speech processor from the drop down list.

Mapping change may be necessary.

When programming a child's speech processor for use with FM it is recommended to use a mixing ratio that does not attenuate the signal from the speech processor microphone, such as 50/50.

Fitting

1. Turn the FM transmitter, MicroLink receiver and Harmony/Auria processor off.
2. When using MLxS ensure that the pins are in the horizontal orientation

3. Turn the Harmony/Auria off by sliding the battery back.

4. Remove the standard earhook by twisting it off.

5. Hold the iConnect at the base and firmly press until it clicks onto the processor.

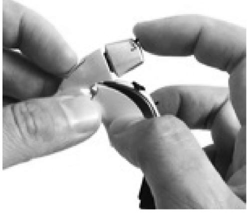
APPENDIX A (*Continued*)

6. Insert a size 10 zinc air battery into the iConnect (+side up)
NOTE: Only ZeniPower size A10 batteries from Advanced Bionics are certified for use with the iConnect in order to ensure reliable system operation.

7. Turn the transmitter on.

8. Turn the volume down on the Harmony/Auria to avoid transient sounds.

9. Turn the Harmony/Auria on to a program with an appropriate mixing ratio.



10. Turn the MicroLink receiver on to the single green dot position.
(For reliable system use, we recommend to set the MicroLink receiver to DPAI=Yes.

11. Gradually turn the volume on the Harmony/Auria up to the normal level (usually 12:00)

12. Verify that the FM is loud but confortable for the listener. This may be done by determining speech recognition in quiet through the FM only. Confirm that performance is similar to the CI only condition. If not, it may be necessary to change the gain programmed in the MLxS from the +10 default.

13. Verify that the FM is beneficial in noise. If not, it may be necessary to use a program with a 30/70 mixing ratio.

Suggested Harmony/Auria mixing ratio settings
50/50: for quiet environments

30/70: for moderate noisy environments (e.g. school)

Aux Only: for noisy situations

APPENDIX A (*Continued*)

Listening Check/Troubleshooting

1. Follow the CI audiologist's recommendations for checking performance of the Harmony/Auria.

2. To check the FM system, remove the MicroLink and plug it into a working hearing instrument and audio shoe or a Phonak MicroLink Headset checker (Ref. No. 052-3122). Turn on the transmitter and listen for a clear signal.

2. The Auria-iConnect Earhook

Advanced Bionics Order Ref. No. Silver Metallic: CI-5751-100, Dark Sienna: CI-5751-200, Beige: CI-5751-300
Phonak Order Ref. No. Silver Metallic: 052-0412-00057, Dark Sienna: 052-0412-00058, Beige: 052-0412-00059.

3. The MLxi Receiver

AutoConnect automatically detects whether the FM receiver is attached to a "DPAI yes" or "no" hearing instrument and corrects its output impedance accordingly.

Lock MLxi Button

The MLxi push button can be either locked or activated.

"Locked"-mode: In this mode, the MLxi functions automatically and this mode is recommenjded for all children.

"*Activated"-mode:*
The switch works as: ON/OFF

APPENDIX B Example of downloadable user guide for frequency modulated (FM) system with advanced bionics implant.

User Guide for Advanced Auria Bionics Cochlear Implant with Phonak FM Systems

1. Switch on the FM transmitter, MicroLink and then the Harmony/Auria processor, *in that order, to avoid transient sounds.*

2. Switch on the MLxi Receiver

Lock MLxi Button

The MLxi push button can be either locked or activated.

"Locked"-mode: In this mode, the MLxi functions automatically and this mode is recommenjded for all children.

"*Activated"-mode:* Just press the button to turn it on.

3. Switch on the inspiro

Push the slider to the left until the green mark appears and the LCD is illuminated.

To save power, the backlight of the inspiro LCD is switched off after a certain time. Press any button to activate the LCD backlight.

To switch off inspiro, push the slider to the right.
The inspiro can also be switched off if the keypad is locked!

APPENDIX B (*Continued*)

Wearing inspiro

inspiro can either be worn on the belt by using the clip.....

...or around the neck by using the lavalier.

Wearing iBoom

iBoom is an ultra-lightweight boom microphone. Extremely comfortable to wear, it can be worn on the left or right ear and adjusts easily to fit all ear and head sizes.

How to fit the iBoom to the ear:

Open the loop carefully and attach the iBoom to the left or right ear.

Hold the iBoom with one hand and slightly pull the black lever with the other hand to reduce the diameter of the earloop until the iBoom holds securely.

Adjust the boom arm in order to bring the microphone as close to the mouth as

APPENDIX B (*Continued*)

possible.

Fix the clip on your clothes as depicted and make sure the cable is not stretched between the clip and the ear.

5. Description

1. ON/OFF slider
2. Color LCD
3. Softkeys
4. Keypad lock and return key
5. Microphone mute key

6. Audio input (3.5 mm)
7. Mini USB for charging

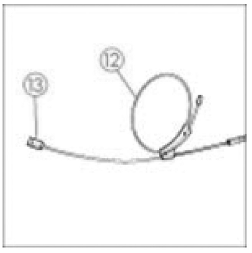
8. Button to attach the belt clip and the lavalier
9. Cable wrapper

iLapel microphone

10. Microphone openings (do not cover)
11. Wearing clip

iBoom microphone

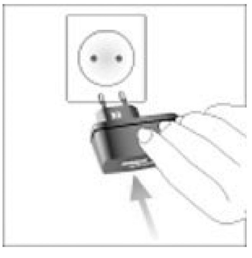
APPENDIX B (*Continued*)



12. Adjustable ear loop
13. Microphone (do not cover)

Charging inspiro

inspiro contains a re-chargeable built-in state-of-the art lithium polymer battery with fast-charge capability.
A fully-discharged battery will charge to 80% in one hour and 100% in 2 hours.



Select an easily accessible socket outlet and plug the charging unit into the socket outlet.

Connect the MiniUSB plug from the charging unit to the inspiro.

Note: Use only the original Phonak charging unit for inspiro.

Operating range (FM transmission)
The inspiro uses the microphone cable as an antenna. Therefore, always ensure that the cable is unwound while you are using the inspiro.

Used with Phonak FM receivers, the inspiro should operate over a range up to 40 meters (120 feet) depending on the surroundings.
Note: High-power electronic equipment, large electronic installations and metallic structures may impair and significantly reduce the operating range.